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Indian Standard

IS 17951 : 2023

पवन जनित मलबे की टक्कर से भवन के बाहरी सतह की सुरक्षा से संबधित कार्यकारिता ज्ञात करने की विधि

Method for Determination of Performance Relating to Safety of External Building Envelope Impacted by Wind Borne Debris

ICS 91.120.99

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Cyclone Resistant Structures Sectional Committee, CED 57

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Cyclone Resistant Structures Sectional Committee had been approved by the Civil Engineering Division Council.

Windows, doors, curtain walls, roof and wall cladding systems are building envelope components often subjected to damage in cyclone or high speed wind. The adequacy of the structural design is substantiated by accounting for the design load as given in IS 875 'Code of practice for design loads (other than earthquake) for buildings and structures' in different parts, which discuss proof loads as added factors of safety. However, these do not account for other factors such as the impact of wind borne debris caused due to cyclone or high speed wind. Wind borne debris present in cyclone or high speed wind has been causing a significant amount of damage to building envelopes. The actual in-service performance of fenestration assemblies and impact protective systems in areas prone to severe high speed wind depends on many factors. The main factors that affect the actual loading on building surfaces during a severe windstorm include varying wind direction, duration of the wind event, height above ground, building shape, terrain and surrounding structures. The resistance of fenestration or protective systems assemblies to wind loading after impact depends upon the product design, installation, load magnitude, duration and repetition.

The damage caused by wind borne debris during cyclone or high speed wind goes beyond the failure of building envelope components, such as windows, doors, and curtain walls. Breaching of the envelope exposes a building's contents to the damaging effects of continued wind and rain. A potentially more serious result is internal pressurization. When the windward wall of a building is breached, the internal pressure in the building increases, resulting in increased outward acting pressure on the other walls and the roof.

This standard covers types of generally occurring impact loads, and provides necessary testing methods and acceptance criteria against these type of impact loads which are generated on external building envelope by wind borne debris.

The impact bodies may be loose objects which are kept near buildings premises, wooden logs, may be small or big, and any hard particles/pebbles, etc. Their mass may range from small pebbles of 5 g to 1 kg to big objects like 4 kg to 50 kg.

Exterior windows, glazed curtain walls, doors, skylights, louvers, vents and cladding elements being façade entities for any buildings are necessary to be tested and verified for these wind borne debris impact loads.

This standard applies to the design of entire fenestration or impact protection systems assemblies and their installation. The performance determined by this standard relates to the ability of elements of the building envelope to remain unbreached during a windstorm.

In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by deriving assistance from the following publications:

> ASTM E1886-05 'Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials'
>
> ASTM E1996-09 'Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes'
>
> Report No. 15775; 'Simulated Wind Driven Debris Impact Testing of External Personal Access Doors'

(*Continued on third cover*)

Indian Standard

METHOD FOR DETERMINATION OF PERFORMANCE RELATING TO SAFETY OF EXTERNAL BUILDING ENVELOPE IMPACTED BY WIND BORNE DEBRIS

1 SCOPE

This standard provides the method for determination of performance relating to safety of external building envelope like glazed curtain walls, exterior doors, exterior windows, impact protective systems (shutters, screens), skylight, wall cladding system, etc, impacted by wind borne debris, for buildings and other structures located in geographic regions that are prone to cyclone or extreme wind events.

2 REFERENCES

The following standards contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards listed below:

IS No.	*Title*
IS 190 : 1991	Coniferous sawn timber (baulks and scantlings) — Specification (*fourth revision*)
IS 280 : 2006	Mild steel wire for general engineering purposes (*fourth revision*)

3 TERMINOLOGY

For the purpose of this standarads, the following terms and their definitions shall apply:

3.1 Fenestration Assembly (External)

The construction intended to be installed to fill an intended opening in exterior envelope.

3.2 Impact Protective System

The construction applied, attached, or locked over an exterior glazed opening system to protect that system from wind borne debris during high wind events. Impact protective system includes types that are fixed, operable, or removable.

3.3 Lumber

A dressed piece of surface dry softwood lumber.

3.4 Missile

The object which is propelled toward a test specimen.

3.5 Test Specimen

The entire assembled unit submitted for testing.

3.6 Windborne Debris

The objects carried by the wind in cyclone or high speed wind.

4 TEST CRITERIA

4.1 Test Impact Loads

The test impact load as given in Table 1, shall be applied for height up to 10 m by means of missile on the external envelope of the building, which depends upon the level of protection and the distance from the coastline.

Test beyond the height of 10 m may be performed as per the agreement between the interested parties in view of the vicinity of the structure and other factors.

Table 1 Detail of Missiles and Their Impact Speed
[*Clauses* 4.1, 6.4 (a) *and* 6.4 (b)]

Sl No. (1)	**Type of missile** (2)	**Level** (3)	**Missile** (4)	**Impact Speed** m/s (5)
i)	Small missile (Steel ball)	A	No. of balls = 10 Shape = Spherical Mass = (2 ± 0.1) g Diameter = 8 mm	40
ii)	Large missile (Wooden lumber)	B	Mass = (2 050 ± 100) g Cross section = (100 x 50) mm^2 Length = 1.2 m ± 100 mm	12
iii)		C	Mass = (4 100 ± 100) g Cross section = 100 x 50 mm^2 Length = 2.4 m ± 100 mm	15
iv)		D	Mass = (4 100 ± 100) g Cross section = 100 x 50 mm^2 Length = 2.4 m ± 100 mm	24

NOTE — Tolerance of ± 1 percent shall be taken, in case tolerance is not mentioned.

4.2 Test Sequence

The test specimen shall be subjected to test by applying the large missiles first and subsequently by the small missile.

4.3 Level of Protection

4.3.1 For this test, buildings are classified in three categories as given below:

a) Enhanced Protection (Essential Facilities)

Buildings and other structures designated as essential facilities, including, but not limited to, hospitals; other health care facilities having emergency treatment facilities; jails and detention centres; fire, rescue and police stations, and emergency vehicle garages; designated emergency shelters; Communication centres and other facilities required for emergency response; power generating stations; other public utility facilities required in an emergency; and buildings and other structures having critical national defence functions.

b) Basic Protection

All buildings and structures except those listed in **4.3.1** (a).

c) Unprotected

Buildings and other structures that represent a low hazard to human life in a windstorm including, but not limited to agricultural facilities, production greenhouses, certain temporary facilities, and storage facilities.

4.3.2 Based on the level of protection and the distance of building from the coastline, the test impact load shall be applied as given in Table 2. However as per the agreement between the interested parties, stringent level of test impact load may be performed.

Table 2 Test Impact Load to be Applied
(*Clause* 4.3.2)

Sl No.	**Distance from Coastline**	**Test Impact Load**		
		Enhanced Protection (Essential Facilities)	Basic Protection	Unprotected
(1)	(2)	(3)	(4)	(5)
i)	Greater than 60 km and up to 100 km	C + A	B + A	None
ii)	Less than equal to 60 km	D + A	C + A	None

NOTES

1 A, B, C and D are as given in Table 1.

2 Test beyond 100 km from the coastline, may be performed, considering the vulnerability of structures in view of vicinity of the structure and other factors.

5 TEST SPECIMEN AND LOCATION OF IMPACT

5.1 Test Specimen

The test specimen shall be of full size, as utilized in actual use. The installation methodology shall also be as per the actual use. Number of test specimen shall be decided such that one specimen shall not be impacted by more than two large missile test and one small missile test.

5.2 Location of Impact

For the large missile tests, the locations given in **5.2.1** to **5.2.6** should be taken into consideration. If specimen passes the large missile test, it will be tested for small missile test with ten spherical steel balls at random locations. Location other than given in **5.2.1** to **5.2.6** may also be tested as per the agreement between the interested parties in view of the operational and functional requirements of the specimen.

Large missile shall be impacted within radius of 65 mm from the centre of impact location. In case of interface corner, the location of impact shall be 150 mm away from the corner.

5.2.1 *Windows*

Full size windows shall be tested as an assembly consisting of the glazing and its typical frame including any seals. The assembly shall be subjected to the test at the following location:

a) Geometric centre, and
b) Interface corner.

Where interior mullions are present, additional impacts are to be performed at the following locations:

a) Centre of mullion, and
b) Base/end of mullion.

5.2.2 *Doors*

Full size door shall be tested as an assembly consisting of the door and its typical frame. For single leaf door, the assembly shall be subjected to the test at following locations:

a) Geometric centre, and
b) Interface corner.

In the case of double leaf door assembly, an additional impact shall be performed at the following location: centre meeting point or mullion.

5.2.3 *Impact Protection Systems*

5.2.3.1 Full size impact protection systems such as shutters or screens shall be tested as a system consisting of the shutter or screen and its typical frame, including any accessories, if applicable. The impact protection system shall be subjected to the test at the following locations:

a) Geometric centre, and

b) Interface corner.

Where interior studs or supports are present, additional impacts shall be performed at these locations:

a) Centre of interior stud/support, and
b) Base/end of interior stud/support.

5.2.4 *Roof, Skylight and Wall Cladding Systems*

Roof, skylight and wall cladding shall be tested as a system. A test cladding system consists of two sheets assembled together as it will be in practice. The assembled system shall be subjected to the test at the following locations:

a) Geometric centre of one sheet,
b) Interface corner of one sheet,
c) Adjacent to lap on underlapped sheet at midspan, and
d) Adjacent to lap on underlapped sheet adjacent to end support.

5.2.5 *Wall Panel Systems*

Wall panels shall be tested as a system. A test wall panel system consists of two panels, their usual supports and fasteners assembled together as it will be in practice. The assembled system shall be subjected to the test at the following locations:

a) Geometric centre of one panel,
b) Interface corner of one panel,
c) Directly on panel to panel interface joint, and
d) Directly on panel sheet at midspan adjacent to the other panel.

The above impact locations are for flat surface wall panels. In the case of profiled wall panels, additional tests may be required.

5.2.6 *Other Wall and Roof Assembly*

Wall and roof assembly other than **5.2.1** to **5.2.5** such as continuous masonry/concrete/metal units shall be tested in full size as utilized in actual use, but not greater than 3 m x 3 m. The sample should be supported as it will be in practice. The assembled system shall be subjected to the test at the following locations:

a) Geometric centre, and
b) Interface corner.

6 TEST APPARATUS

The test apparatus shall have major components as given in **6.1** to **6.4**.

6.1 Mounting Frame

The mounting frame shall be a fixture which supports the test specimen in a vertical position during testing. The maximum deflection of the longest member of the mounting frame during impact shall not exceed $L/360$, where L denotes the longest unsupported length of a member of the mounting frame. Deflection measurements shall be made normal to the plane of the specimen at the point of maximum deflection. The mounting frame shall be either integral with the test chamber or capable of being installed into the test chamber prior to or following missile impact(s). The mounting frame shall be anchored such that it does not move when the specimen is impacted.

6.2 Missile Propulsion Device(s)

It shall be any device capable of propelling the missile at a specified speed, orientation, and impact location. The missile shall be such that it does not accelerate upon impact due to the force of gravity along a line normal to the specimen. The details of typical missile propulsion device are given in Annex A for reference.

6.3 Speed Measuring Systems

6.3.1 These shall be speed measuring devices, such as photoelectric sensors, high speed video camera and standard video camera.

6.4 Missiles

The missiles shall be as given below:

a) Small Missile

It shall be solid spherical steel balls as per Table 1 made of steel conforming to IS 280, having a mass of (2 ± 0.1) g.

b) Large Missile

It shall be made of softwood as per IS 190 or any equivalent timber. The missile shall have no defects, including knots, splits, checks, shakes or wane within 300 mm of the impact end. The cross-section, mass and length of the different large missile shall be given in Table 1.

7 TEST PROCEDURE

7.1 Preparation

7.1.1 Remove from the test specimen any sealing or construction material that is not intended to be used when the unit is installed in or on a building. Support and secure the test specimen into the mounting frame in a vertical position. The test specimen shall not be removed from the mounting frame at any time during the test sequence.

7.1.2 Unless specified otherwise, for more stringent conditioning, condition the specimens for 4 h within a temperature range of 15 °C to 40 °C.

7.1.3 Secure the specimen and mounting frame such that the missile will impact the exterior side of the specimen as installed.

7.1.4 Locate the end of the propulsion device from which the missile will exit at a distance from the specimen equal to 1.5 times the length of the missile, but shall be not less than 1.80 m. The distance for small missile test is same as distance taken for large missile test on the same specimen.

7.1.5 Weigh each missile within 15 min prior to impact and load the missile into propulsion device. Align the missile propulsion device such that the specified missile will impact the test specimen at the specified location.

7.1.6 Reset the speed measuring system. The measured missile speed will be within the following respective tolerances at any point after the missile acceleration caused by the propulsion device equals zero:

± 2 percent specified speed; when speed is ≤ 23 m/s
± 1 percent specified speed; when speed is > 23 m/s

7.2 Propulsion of Missile

7.2.1 Propel the missile at the specified impact speed and location.

7.2.2 For missiles having a longitudinal axis, on impact the longitudinal axis of the missile shall be within 65° ± 5° of a line normal to the specimen at the specified impact point.

From a horizontal datum, measure the vertical height to the centre of the exit end of the propulsion device (if it is horizontal), H, and the vertical height to the centre of the missile impact point on the specimen, h. To ensure the missile rotates less than 5° prior to impact:

$$5^\circ \leq \tan^{-1}\left[\frac{H-h}{d}\right]$$

where d denotes horizontal distance from the exit end of the propulsion device to the specimen.

7.2.3 Repeat these steps for all impact locations as specified for the specimen.

8 ACCEPTANCE CRITERIA

8.1 The acceptance criteria for the large missile test are as follows:

a) If large missile did not penetrate and no obvious tear formation is present on the inner side : Pass

b) If test specimen stops the missile but is left with a tear formation smaller than 130 mm long or 1 mm wide : Pass

c) If test specimen stops the missile but is left with a tear formation greater than 130 mm long or 1 mm wide : Fail

d) If test specimen stops the missile but the missile is visible from the inside (that is, protruding through test specimen) : Fail

8.2 If test specimen passes the large missile test at all critical locations, impact the same specimen with small missile test at random location. The acceptance criteria after the small missile test are as follows:

a) If none of the spherical steel balls penetrates through the test specimen : Pass

b) If any of the spherical steel balls penetrates through the test specimen : Fail

9 INFORMATION SUBMITTED BEFORE TESTING

The following information should be provided with test request of specimen.

a) Level of protection as per **4.3**,
b) Test impact load if other than Table 2,
c) Description of the test specimen such as dimensions, mass, material and framing system (if applicable),
d) Detail of installation method with all supporting devices/materials, and
e) Location of impact if other than **5**.

10 TEST REPORT

The following information should be mentioned in the test report.

a) Name of the test;
b) Client details;
c) Referred Indian standard;
d) Information submitted with test request of specimen;
e) Date of test;
f) Test report number;
g) Identification number of the test specimen;

h) Description of the test specimen, such as dimensions, mass, material and framing system (if applicable);
j) Description of mounting frame used for testing and the details of installation of specimen on mounting frame;
k) Details of conditioning of specimen;
m) Description of missile;
n) Location of impact for large missile test on test specimen;
p) A statement of whether, upon completion of testing, the test specimen pass or fail in accordance with referred Indian standard or any specified criteria as per the agreement between interested parties; and
q) Any other information as found necessary.

ANNEX A

(*Clause* 6.2)

MISSILE PROPULSION DEVICE

A-1 The main components, test apparatus, assembly, and operation of missile propulsion devices shall be as given in **A-1.1** to **A-1.6.**

A-1.1 Large Missile Air Cannon

A-1.1.1 The large missile air cannon shall use compressed air to propel the large missile. The cannon shall be capable of producing missile impact at the defined locations and speed. It shall consist of four major components : a compressed air supply, a pressure release valve, a barrel and support frame, and a speed measuring system for determining the missile speed.

A-1.1.2 The barrel of the large missile cannon shall consist of a 100 mm nominal inside diameter pipe and shall have a length at least as long as the missile. The total length of the barrel shall be the distance from the pressure valve to the vent holes in advance of the timing system or to the mouth of the barrel. The barrel of the large missile cannon shall be mounted on a support frame in a manner to facilitate aiming the missile so that it impacts the specimen at the desired location.

A-1.1.3 The end of the missile that impacts the target is denoted as the missile’s impactend. The end of the missile opposite to the impact end is denoted as the missile’s trailing edge. A sabot shall be used at the trailing edge of the missile to facilitate launching.

A-1.1.4 The speed of the missile shall be measured on the trailing edge of the missile after it exits the barrel. The photoelectric sensors can be mounted on an extension of the barrel or supported independently of the cannon. In either case, the missile shall not be accelerated as its trailing edge passes between the photoelectric sensors.

A-1.2 Bungee Test Apparatus

The following are the suggested components of bungee test apparatus:

a) A rigid PVC (or other suitable) pipe having a 100 mm nominal inside diameter and a minimum length of 2.75 m.

b) Three to five 7.62 m long having 10 mm outside diameter and 5 mm inside diameter latex rubber surgical tubings banded together.

c) One 50 mm × 100 mm × 150 mm wooden block with threaded eye hook mounted to and projecting from either face of 100 mm × 150 mm size.

d) Two through-beam photoelectric sensors of the same make and model with minimum tolerances of ± 2 percent (*see* **A-1.6**)

e) Mounting frame of general construction capable of supporting pipe and timing system without movement during test.

f) One 3 m steel cable with a quick release snap hook attached to one end.

g) Hand operated cable winch with ratchet lock.

A-1.3 Assembly

The assembly shall be done as given below, the typical detail of missile propulsion devices being as given in Fig. 1:

a) Drill two holes through each side of the PVC pipe one at 610 mm and another at 1 520 mm from one end of the pipe, respectively. Holes should be of sufficient size to allow the light beams from the photoelectric sensors to pass through the holes unobstructed across the diameter of the pipe.

b) Mount the photoelectric sensors on the pipe such that the light beams pass through the respective holes from one side of the pipe to the other across the pipe’s diameter.

c) Drill one hole through each side of the PVC pipe approximately 150 mm from the end of the pipe upon which the sensors are mounted. These holes should be located 90° around the pipe circumference from the holes described in **A-1.3 (**a).

d) Thread each end of the surgical tubing bundle through one of the respective holes and fix the ends such that they cannot pull out. Pull the centre of the bundle through the pipe such that it exits the pipe at the opposite end.

e) Attach the wooden block to the surgical tubing bundle such that the centre of the block is aligned with the centre of the bundle. The 100 mm × 150 mm face of the block with the eye hook protruding from it should face away from the end of the tube from which the tubing bundle exits.

f) Mount the tube/surgical tubing assembly to the frame as illustrated in Fig. 1.

g) Mount the hand winch to the frame in the illustrated location. Fix the end of the steel cable that does not have the quick release snap hook to the winch and rap the cable around the drum of the winch. The end of the cable with the snap hook should hang free.

h) Connect the quick release snap hook to the eye hook of the wood block and draw enough cable on the winch drum to place a slight tension in the surgical tubing bundle.

A-1.4 Operation

The device shall be propelled as follows:

a) Place the large missile in the pipe such that the trailing end of the missile rests on the wood block of the surgical tubing bundle.

b) Crank the hand winch to draw wooden block back to cause tension in the surgical tubing bundle. The amount of tension caused in the bundle is based on the number of tubes in the bundle and the required missile propulsion speed.

c) Reposition the missile such that the end is centered on the wooden block.

d) Set up zero timing system for speed measurement.

e) Align pipe such that the projected missile will impact the test specimen at the specified location.

f) Release retaining pin of the quick release snap hook to release wooden block and propel missile.

A-1.5 Small Missile Cannon

A compressed air cannon shall be used that is capable of propelling missiles of the specified speed. The cannon assembly shall comprise a compressed air supply, a remote firing device and valves, a barrel, and a timing system. The small missile cannon shall be mounted on a frame designed to permit movement of the cannon so that it can propel missiles to impact the test specimen at specified locations. The photoelectric sensors shall be positioned to measure missile speed within 1.50 m of the impact point on the test specimen.

A-1.6 Photoelectric Sensors

Two photoelectric sensors shall be used. Both photoelectric sensors shall be the same model. An electronic timing device shall be activated when the reference point of the missile passes the first sensor. The electronic timing device shall be stopped when the reference point of the missile passes the second sensor. The electronic timing device shall have an operating frequency of not less than 10 kHz with a response time not to exceed 0.15 ms. The speed of the missile shall be determined by dividing the distance between the two through-beam photoelectric sensors by the time interval counted by the electronic timing device.

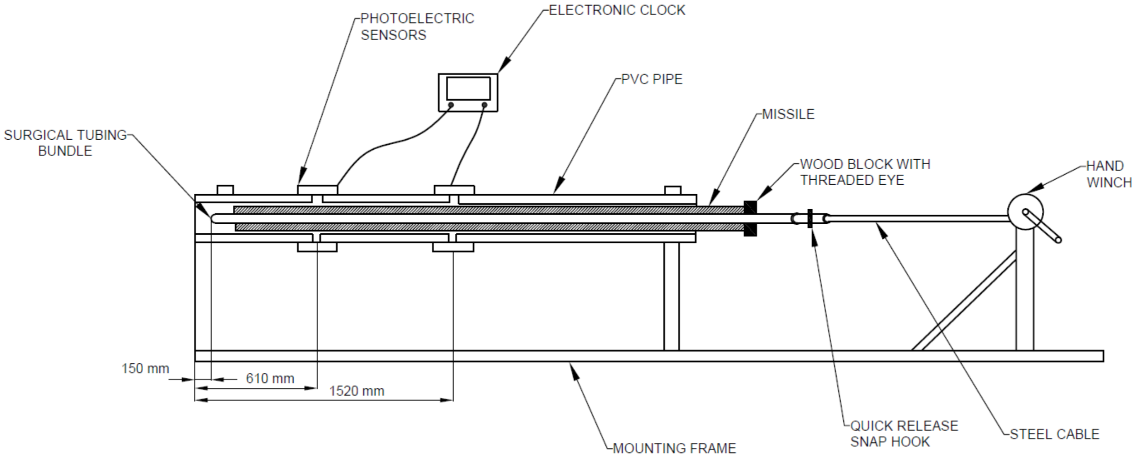

FIG. 1 TYPICAL DETAILS OF MISSILE PROPULSION DEVICE

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Cyclone Resistant Structures Sectional Committee, CED 57

Organization	*Representative(s)*
In Personal Capacity (*B-03-3, Raheja Atlantis, National Highway 08, Sector 31- 32A, Gurugram*)	Dr Prem Krishna (***Chairperson***)
Adlakha Associates Private Limited, New Delhi	Shri Pramod Adlakha Shri Abhaya Adlakha (*Alternate*)
BES Consultants Private Limited, Mumbai	Shri Rajan Govind Shri Venugopal S. B. (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Achal Mittal Shri Siddharth Behera (*Alternate*)
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Engineers India Ltd, New Delhi	Dr G. G. S. Achary Shri Bhaskar Pal (*Alternate*)
Housing & Urban Development Corporation Ltd, New Delhi	Shri Deepak Bansal
India Meteorological Department, New Delhi	Shrimati Sunitha Devi. S Shrimati Monica Sharma (*Alternate*)
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Indian Institute of Technology Kanpur, Kanpur	Dr Rajeev Gupta
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Indian Society for Wind Engineering, Roorkee	Prof Mahesh Tandon Prof Ajay Gairola (*Alternate*)
Jaypee University of Engineering and Technology, Guna	Dr S. Arunachalam

Organization	*Representative(s)*
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Larsen and Toubro Limited, Mumbai	Shrimati Bala Saraswathi Ilango Shri R. John Sandeep (*Alternate*)
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National Disaster Management Authority, New Delhi	Ms Ranu Chauhan Shri Javed Iqbal (*Alternate*)
National Institute of Ocean Technology, Chennai	Shri A. Sataya Kiran Raju Shri K. Mullaivendhan (*Alternate*)
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BIS Directorate General	Shri Arunkumar S., Scientist 'E'/Director and Head (Civil Engineering) Representing Director General (*Ex-officio*)]

Member Secretary
Dr Manoj Kumar Rajak
Scientist 'D'/Joint Director
(civil engineering), BIS

(*Continued from second cover*)

The composition of the committee responsible for the formulation of this standard is listed in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 Rules for rounding of numerical values (*second revision*). The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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